Quieter Pavements & Pervious Pavements

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Quieter Pavements

- Why?
- What?
- Where?
- How?
Why Quieter Pavements?

- People, People and more People
- 300 million Americans nationwide
- 20% growth per decade (2%/yr)
- Could reach 11 million in 30 years
- Increasing complaints about traffic noise
  - Focused on urban areas (but expanding)
  - Growing traffic and growing population, especially living close to highways = growing noise
  - Sound walls not enough
What are Quieter Pavements?

- What makes roadway noise
  - At speeds greater than 50 mph
    - 70 to 90 percent from tire/pavement interface
    - Remaining 10 to 30 percent – engine, exhaust, wind, mechanical clanking

- Noise reduction results from surface texture
  - For asphalt pavements
    - Finer gradation → quieter the pavement
      - Aggregate size < 3/8 inch
      - Need 15-20 percent air voids
      - Europeans find a two layer concept with ¾ inches of fine graded OGFC over 1-½ inches of coarse graded OGFC provides best noise reduction
  - For concrete pavements
    - New (wet) concrete surface texturing (carpet drag, tining)
    - Existing concrete - “whisper” grinding
How can pavement be quieter?

- By capturing noise in holes, grooves, textures
- By making the road smoother – less noise to begin with
Asphalt Pavement - Surface Texture

Open-graded friction course

Dense-graded Hot Mix Asphalt

1″
Concrete Pavement – Surface Texture

Grinding

Carpet Drag

Longitudinal Tining
What pavements are quieter?

- Open Graded Asphalt?
- Dense Asphalt?
- Concrete?
- Porous Concrete?
- Additives in Asphalt or Concrete?
- Smoother pavement?
- Warmer pavement?
- Other?

Answer --- It depends...
What are Typical Pavement Sound Levels?

On-Board Sound Intensity (dBA)

- Dense-graded Asphalt
- Open-graded Asphalt
- Concrete
Experience of other states

- Southern states (AZ, CA, FL, GA, NC, SC and TX) indicate average life of 8-10 years
  - Placement temperature
    - AZDOT requires minimum 85ºF pavement surface temperature
    - CALTRANS allows 60ºF air temperature
    - Contractor (Granite Construction) prefers 70ºF air temperature
    - Challenge will be placement during night time construction in western WA (contract allowed 55ºF air temperature)
Arizona Performance

SR-17
118,000 ADT
8 to 9 years old

Photo courtesy of Joe Mahoney
Arizona Performance
Reflective cracking in OGFC-AR over PCCP

Photo courtesy of Joe Mahoney
ARFC over PCC transverse joint—broad view
Noise Level for Asphalt Pavements vs. Time (Arizona DOT)
WA State Experience

- Studded tires
  - No use to minimal use in southern states
  - Can be a major issue in WA
  - Class D has been a problem

Studded tire wear on Class A pavement
WSDOT Experience – Class D

Years to 1/2 Inch Rutting

![Graph showing the relationship between years to 1/2 inch rutting and vehicles per day per lane (thousands).]
Asphalt Binder Types

- Asphalt rubber
  - Incorporates recycled tires (tread only)
  - Improves durability (aging) properties of the asphalt binder
  - Contributes ~1 dB(A) noise reduction

- Polymer modified
  - Rubber (not recycled tire) product
    - Typically a styrene-butadiene-styrene (SBS)
  - Improves durability (aging) properties of the asphalt binder
  - Contribution to noise reduction, if any, is unknown

\[
\begin{align*}
\text{Poly(styrene-butadiene-styrene) or SBS}
\end{align*}
\]
## Current Activities – Quieter Pavement

### Asphalt Test Sections

<table>
<thead>
<tr>
<th>State Route</th>
<th>Project Location</th>
<th>Test Section</th>
<th>Existing Pavement Type</th>
</tr>
</thead>
</table>
| 5           | 52\textsuperscript{nd} Ave West to SR-526 (southbound only) Construction in 2006 Complete | OGFC-AR (~¾ mile)  
OGFC-SBS (~¾ mile)  
HMA (remainder of project) | Hot mix asphalt pavement |
| 520         | 1.5 mile section east of Lake Washington (both directions) Construction in 2007 Complete | OGFC-AR (~½ mile)  
OGFC-SBS (~½ mile)  
HMA (~½ mile) | Hot mix asphalt pavement |
| 405         | 112\textsuperscript{th} Ave SE to SE 8\textsuperscript{th} St (both directions) Construction in 2007 - 2009 | OGFC-AR (~1¼ mile)  
OGFC-SBS (~ 1¼ mile)  
HMA (~1 mile)  
Diamond grinding (~1½ mile) | Hot mix asphalt and concrete pavement |
Crumb Rubber Usage

- One ton OGFC-AR contains 33.2 lbs crumb rubber
- One lane mile of OGFC-AR contains approximately 300 tons of crumb rubber
- Assuming average passenger tire weighs 18 lbs → 550 tires per lane mile
- Lynnwood project (1,686 tons OGFC-AR) used approximately 3,100 tires
- Eastside project (910 tons OGFC-AR) used approximately 1,670 tires
- Crumb rubber requires additional mixing equipment at the HMA plant
- SBS can be incorporated directly into the PG graded liquid asphalt
Test Project Details (I-5, Lynnwood)

- Constructed August 2006
- South bound only
- OGFC-AR
- OGFC-SBS
- ½” Dense-graded HMA

HOV    Lane 3    Lane 2    Lane 1
# HMA Bid Item Summary (I-5, Lynnwood)

<table>
<thead>
<tr>
<th>Bid Item</th>
<th>Estimated Quantity</th>
<th>Engineer's Estimate</th>
<th>Wilder (low bid)</th>
<th>Cost per ln-mi</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Class ½” PG 64-22 (tons)</td>
<td>28,853</td>
<td>$59.00</td>
<td>$62.50</td>
<td>$45,188</td>
</tr>
<tr>
<td>OGFC-AR (tons)</td>
<td>1,686</td>
<td>$74.00</td>
<td>$130.00</td>
<td>$39,091</td>
</tr>
<tr>
<td>OGFC-SBS (tons)</td>
<td>2,441</td>
<td>$67.00</td>
<td>$90.00</td>
<td>$27,063</td>
</tr>
</tbody>
</table>
Mix Design Details

- **OGFC-AR (Open Graded Friction Course, Asphalt Rubber modified)**
  - PG 64-22
  - 3/8 inch maximum aggregate size
  - 9.2 percent binder content

- **OGFC-SBS (Open Graded Friction Course, SBS rubber modified)**
  - PG 58/64-22 modified to meet PG 70-22
  - 3/8 inch maximum aggregate size
  - 8.3 percent binder content
  - Fibers added for draindown
Plant Operations

Photo courtesy of Steve Muench
Plant Operations

Photo courtesy of Steve Muench
Plant Operations
Paving Operations

Photo courtesy of Joe Mahoney
Paving Operations

Photo courtesy of Joe Mahoney
Paving Operations

Photo courtesy of Joe Mahoney
Paving Operations – Soap???
Paving Operations
Things to Watch
Things to Watch

Photo courtesy of Joe Mahoney
Things to Watch
Things to Watch
Things to Watch

- The case of the missing Shuttle Buggy
  - Special Provisions require the use of a Shuttle Buggy
  - 20% voids
  - Stiff binders
  - Night paving
  - Moderately long haul (>1/2 hour)
- What happens if the Shuttle Buggy breaks down? Any guesses?
Things to Watch
Challenges and Opportunities

- Pavement life cycle and life cycle costs
- Safety
- Design details
- Placement temperature
  - ADOT spec pavement surface temperature > 85°F
  - Night paving???
  - Used 55°F on Lynwood test
- Initial and long-term noise reduction
  - National and international question
- Studded tire wear
  - Majority of US quieter pavements constructed in southern climates (Arizona, California, Florida, Georgia and Texas) where studded tire usage is minimal or non-existent
Evaluation Process

• Noise characterization
  – Short-term
    • Initial noise reduction
  – Long-term noise reduction

• Pavement performance
  – Long-term
Noise Characterization

• Measurements
  – On-Board Sound Intensity (OBSI)
  – Statistical Pass By
  – In car

• Frequency
  – Monthly
  – Minimum of twice per year (before and after studded tire period)
Pavement Performance

• Measurements
  – Video Recording
  – IRI (International Roughness Index)
  – INO Scan
    • Rut measurements
• Frequency
  – Minimum of twice per year
    (before and after studded tire period)
Smoothness Results - Lynnwood

- OGFC-AR: 41 (Sep-06), 49 (Oct-08)
- OGFC-SBS: 46 (Sep-06), 54 (Oct-08)
- 1/2-HMA: 64 (Sep-06), 64 (Oct-08)

Average All Lanes Sep-06: OGFC-AR = 41, OGFC-SBS = 46, 1/2-HMA = 64

Average All Lanes Oct-08: OGFC-AR = 49, OGFC-SBS = 54, 1/2-HMA = 64
Wear Results (all lanes) - Lynnwood

<table>
<thead>
<tr>
<th>Material</th>
<th>Average All Lanes Sep-06</th>
<th>Average All Lanes Oct-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>OGFC-AR</td>
<td>1.6</td>
<td>3.2</td>
</tr>
<tr>
<td>OGFC-SBS</td>
<td>1.9</td>
<td>3.4</td>
</tr>
<tr>
<td>1/2-HMA</td>
<td>2.1</td>
<td>2.9</td>
</tr>
</tbody>
</table>
Test Project Details (SR-520, Bellevue)

- Constructed July 2007
- Both directions
- OGFC-AR
- OGFC-SBS
- ½” dense-graded HMA
## HMA Bid Item Summary (SR 520, Bellevue)

<table>
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<tr>
<th>Bid Item</th>
<th>Estimated Quantity</th>
<th>Engineer’s Estimate</th>
<th>Wilder (low bid)</th>
<th>Cost per In-mi</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Class ½” PG 64-22 (tons)</td>
<td>2,840</td>
<td>$110.00</td>
<td>$85.00</td>
<td>$61,455</td>
</tr>
<tr>
<td>OGFC-AR (tons)</td>
<td>910</td>
<td>$225.00</td>
<td>$285.00</td>
<td>$85,700</td>
</tr>
<tr>
<td>OGFC-SBS (tons)</td>
<td>1,190</td>
<td>$200.00</td>
<td>$155.00</td>
<td>$46,609</td>
</tr>
</tbody>
</table>
Test Results: January 2009

SR 520 Medina Initial and Current Noise Levels

- Inaudible: 1 decibels
- Audible: 4 decibels

- Conventional Asphalt
- OGFC-Rubber
- OGFC-Polymer

Average Sound Intensity Level, Decibels

Initial July 2007
- Conventional Asphalt: 100
- OGFC-Rubber: 96
- OGFC-Polymer: 98

Current January 2009
- Conventional Asphalt: 104
- OGFC-Rubber: 104
- OGFC-Polymer: 103
Wear Results (all lanes) - Bellevue

Rutting/Wear (mm)

<table>
<thead>
<tr>
<th>Material</th>
<th>Average All Lanes Aug-07</th>
<th>Average All Lanes Oct-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>OGFC-AR</td>
<td>1.4</td>
<td>2.7</td>
</tr>
<tr>
<td>OFC-SBS</td>
<td>1.7</td>
<td>2.8</td>
</tr>
<tr>
<td>1/2 HMA</td>
<td>1.5</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Average All Lanes Aug-07

Average All Lanes Oct-08
If you’d like to track the results...

- Here’s the website…if just search under quieter pavement...
- [http://www.wsdot.wa.gov/Projects/QuieterPavement/](http://www.wsdot.wa.gov/Projects/QuieterPavement/)
The Team
## Current Activities – Concrete Test Sections

<table>
<thead>
<tr>
<th>State Route</th>
<th>Project Location</th>
<th>Test Section</th>
<th>Existing Pavement Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>Argonne Rd to Sullivan Rd (westbound)</td>
<td>Carpet drag</td>
<td>Concrete Pavement</td>
</tr>
<tr>
<td></td>
<td>Constructed in 2004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Federal Way to S 317th Street HOV Direct Access (both directions)</td>
<td>Carpet drag</td>
<td>Concrete Pavement</td>
</tr>
<tr>
<td></td>
<td>Constructed 2005</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Pierce County Line to Tukwila (Stage 4) (northbound only)</td>
<td>Carpet drag</td>
<td>Concrete pavement</td>
</tr>
<tr>
<td></td>
<td>Constructed 2007</td>
<td>Carpet drag, Longitudinal tining</td>
<td></td>
</tr>
</tbody>
</table>
WSDOT Pavement - Noise Study

- **Noise**
  - Impacts to maintain noise reduction level
  - Include evaluation/discussion of various measurement equipment
  - Examine quieter pavement results in AZ, CA, and TX
  - Conduct interviews with noise specialists

- **Pavement**
  - Investigate usage and performance in AZ, CA, FL, GA, TX and others as appropriate
  - Minimum, maximum and average pavement life (with and without states who allow studded tires)
  - Performance criteria
  - Maintenance information
Tire-Pavement Noise Study

- **Study objective**
  - Provide a forum for states to discuss tire/pavement noise issues and develop a proposed research plan
  - Pool resources and efforts of multiple state agencies and industry to perform tire/pavement noise research in a similar manner (avoiding duplication) and sharing of data

- **Partners**
  - State DOT’s, Federal Highway Administration, Universities, tire manufacturers, consultants, suppliers and industry
Concrete Pavement Texture Study

- Objectives
  - Optimize surface characteristics that address noise without compromising smoothness, friction, and other functional elements of the pavement
- Evaluate various ages of concrete pavement to determine noise and pavement performance characteristics
- Partners: State DOT’s, Federal Highway Administration, Iowa State University, American Concrete Pavement Association
Sound Quantity
Sound Intensity - Concrete

SRTT Tire/Concrete Pavement Noise Sound Intensity
I-5 Federal Way, WA

Average Sound Intensity Level, dBA

Date

- Longitudinal Tining
- Diamond Grind
- Transverse Tining
- Carpet Drag
- Aged
Sound Quantity
Sound Intensity - Concrete

SRTT Tire/Class A and Stone Mastic Asphalt Pavement
Noise Sound Intensity
Moses Lake, WA

Average Sound Intensity Level, dBA

Class A
SMA

Date
10/24/2006

101.0
102.0
103.0
104.0
105.0

104
103
104
103
Sound Quantity
Sound Intensity - Concrete

SRTT Tire/Concrete Pavement Noise Sound Intensity
I-90 Spokane, WA

Date
10/25/2006

Average Sound Intensity Level, dBA
107
106
105
104.5
104
103.5

Transverse Tining
Carpet Drag
Pervious Pavement...?

- Why is there more discussion about Pervious Pavements?
- Where is WSDOT heading with Pervious Pavements?
Pervious Pavement

- **LEED**: Leadership in Energy & Environmental Design
  - A leading-edge rating system for designing, constructing, and certifying the world’s greenest buildings

- **LID**: Low Impact Development
  - Ways to mimic nature by design
Green Buildings

LEED Scoring – 69 points total
1. Sustainable sites: 14 points
2. Water Efficiency: 5 points
3. Energy and Atmosphere: 17 points
4. Materials and Resources: 13 points
5. Indoor Environmental Quality: 15 points
6. Innovation: 4 points
7. LEED Accredited Professional: 1 point

LEED Ratings:
- Platinum: 52-69 points
- Gold: 39-51 points
- Silver: 33-38 points
- Certified: 26-32 points
And now we have Greenroads . . . .

- A rating system that distinguishes sustainable new, reconstructed or rehabilitated roads
- Awards credits for sustainable or environmentally friendly choices
- Certifies projects in a similar manner as the LEED system

http://www.greenroads.us/
What is Pervious Concrete?

- Standard PCC materials are used
- Typically higher cement content for early strength gain (6.5 to 7 sack)
- Little or no fine aggregate (max typically 400-500 lb.)
- Void content as high as 18%
- Max size aggregates from \( \frac{1}{4} \)" to \( \frac{3}{4} \)" have been used
- \( \frac{1}{4} \)" or 3/8" max size provides tightest, smoothest surface appearance.
Benefits of Pervious Concrete

- Saves land and $ required for detention facilities
- Provides primary filtration and treatment
WSDOT Pervious Recommendations for use of Pavement

- Parking areas
- Turnarounds
- Paths & trails
- Low use approaches/roads
- Sidewalks
- Low volume applications
Subgrade Compaction

- Set a minimum – 92 percent T-180 (modified proctor)
- Set a maximum – 96 percent T-180

Aggregate Base Compaction

- Concrete aggregate gradations are standard – aggregates with 30 to 40 percent void space, AASHTO #57 is typical
- Establish a roller pattern
Pavement Design

- Rules of Thumb – Concrete
  - 6” Parking lots
  - 6” Driveways
  - 8” Residential Streets
  - 8” Commercial Driveways

Base
  - 6” or thicker depending on water storage needs

- Typical steps
  - Place ½” high to allow for compaction
  - Compact with roller or plate
  - Joint with special jointing tool
  - Cure with plastic sheeting for 7 days!!!
Pervious Concrete Specification

- A WSDOT Special Provision is available – Based on ACI 522R-06 Recommendations
Pavement Design

- Year: 2000
- Owner: City of Olympia
- 1500 lineal feet of sidewalk
- Sub-grade: native soil was permeable enough
- Savings: $110,000 - land acquisition for detention ponds unnecessary
What is Pervious HMA?

- Open graded HMA mix
- 3/8 to 1/2 in maximum size
- 16% air voids
- Roller pattern compaction
- Very similar to ACP Class D – used in the past
Pavement Design

- **Rules of Thumb – HMA**
  - 2-6” Parking lots
  - 6” Driveways
  - 6-8” Residential Streets
  - 8-10” Commercial Driveways

- **Base**
  - 6 to 8” or thicker depending on water storage needs

- **Typical steps**
  - Let cool slightly (240-250°F) prior to compaction
  - Compact with steel-wheel roller in static mode (non pneumatic)
  - Finish roller
  - Keep traffic off for 24 hours
Pavement Design

- Standard pavement design procedures are used
  - AASHTO
  - PCA

- Reduced flexural strength
  - 250 – 550 psi
Pervious HMA Specification

- A WSDOT Special Provision is available – Based on NAPA Recommendation
  - Currently being modified
  - Several Cities and Counties have used or plan to use the specification
  - Lakeside Industries reported that the specification needs minor tweaks but works well
  - For minor installation use the same gradation for the HMA and storage courses
Specifications Pervious Pavement

Existing Specifications – written by local agencies such as Cities and Counties, Corps of Engineers, Forest Service

These specifications are very loose – requirements such as: “lightly compact the base” or “do not compact the subgrade”

Language used that WSDOT would find difficult to measure
Potential Projects within WSDOT

- Low volume roundabouts
- Bike paths
- Sidewalks